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Log jams at a bridge with a pier and a bridge without pier

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Abstract

A flume experiment was carried out in a rectangular flume in order to investigate interaction between two different model bridges and logs from the viewpoint of flood disaster prevention. Logs is assumed representative of flowing wood during floods. The model bridge with a pier and model bridge without pier were used as an obstruction in rivers. The bridge with a pier is an usual bridge in the Yabe River basin and the bridge without pier is an usual bridge in the Nayoshi River basin. The result reveal that a log jam at a model bridge is determined by shaded area of an obtruction in the channel. In addition, An empirical equation for predicting the volume of woody debris accumulations at bridges is proposed.

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Keywords: log; flood; log jam; woody debris

1. Introduction

Heavy rains hit The Yabe River basin in Yame City and the Nayoshi River basin in Tsuwano Town, Japan on July 14, 2012 and on July 28, 2013, respectively. These heavy rains caused many landslides along the upstream river reachs in the mountain areas and then resulted in floods with a sinificant amount of wood and sediment in the downstream river reachs. Various geomeric features of river such as bridges and riparian trees trapped the flowing wood and formed wood jam. It is important to know the jam at various types of bridges from the viewpoint of flood disaster prevention

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Research on woody debris accumulation during flood is important from the viewpoint of flood defense. The mobility and the accumulation of woody debris in rivers have received much attention from many researchers in the fields of geomorphology and river engineering.

Rusyda et al. [1,2] carried out field investigations into woody debris formed by some obstructions during the 2012 Yabe River flood. The obstructions were bridges and riparian trees in the river and houses on the flood plain. The results clearly showed the dependence of volume of a woody debris accumulation on the shaded area of an obstruction.

There are several previous field studies (*e.g.* [1,2,3]) and laboratory flume experiments (*e.g.* [4,5,6,7]) on behavior of woody debris in rivers. For example, the potential for woody debris accumulation depend on basin, channel and bridge characteristics. Then, A primarily source of the woody debris in rivers is trees undermined by bank erosion [3]. the bridge deck characteristics also had a significant effect on woody debris accumulation [7]. However, little is known about the characteristics of woody debris accumulations during a flood event

The purpose of the present paper is to investigate log jams at a bridge with a pier and a bridge with out pier. Logs is assumed representative of flowing wood during floods. The bridge with a pier is an usual bridge in the Yabe River basin and the bridge without pier is an usual bridge in the Nayoshi River basin.

2. Flume experiment on log jam at model bridges

2.1. Hydraulic model

A flume experiment was performed in a rectangular flume with a smooth acrylic board on both lateral side. The flume was 30 cm wide, 32 cm high and 12 m long. Fig. 1 shows a schematic diagram of the flume.
The flume slope was adjusted to 0.6/100. Inflow flow rate per unit width were about were about 200 cm^2/s , 300 cm^2/s, 300 cm^2/s at the upstream end. The flume bed was divided into movable and fixed part. The movable and fixed bed part were filled with almost uniform sediment grains; the grain density was 2.65 g/cm^3, the representative diameter D_{50}=3.6 mm, the standard deviation s=1.28

A model bridge without piers was installed on the fixed bed part 2.5 m distant from the downstream end. Wooden cylinders pieces were used as the model of floating woody debris in rivers during floods. An experimental apparatus for releasing the model wood on the flow surface was placed at the station 5 m upstream from the model bridge

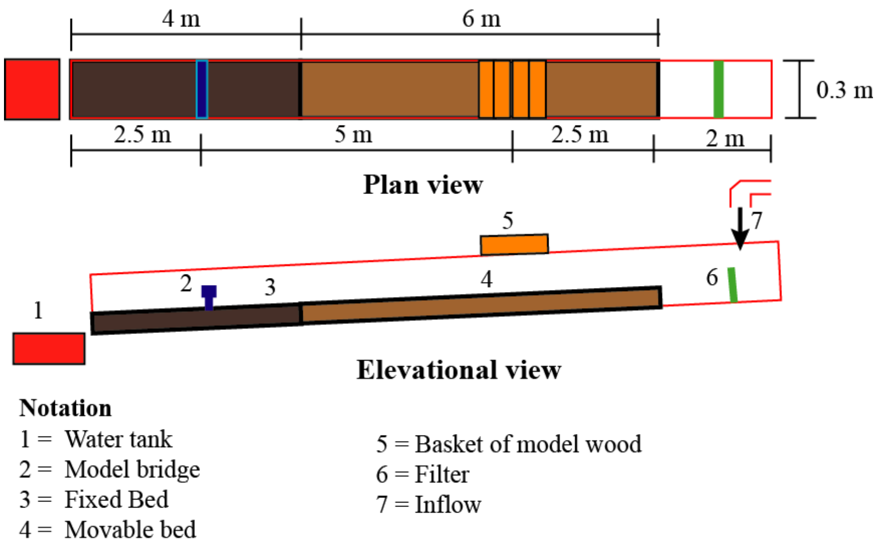


Fig. 1. Experimental Flume

2.2. Model bridge

Model bridge without pier and model bridge wit a pier made of smooth acrylic board was used as an obstruction. The plan, front and side views are shown in Fig. 2. The reduced size of the prototypes were 1/120 for bridge with a pier and 2/100 for bridge without pier.

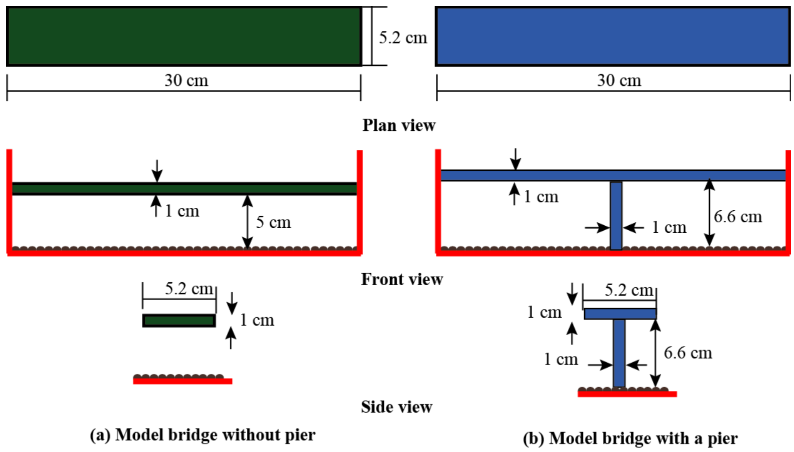


Fig. 2. (a) model bridge without pier; (b) model bridge with a pier.

2.3. Model wood

A model of floating woody debris was simulated by cylinder wood pieces or log (Diameter, D = 2.0 mm and Length, L = 7.0 cm). Prior to a test, the logs were put in a basket after the logs soaked in water for 10 minutes. The log density was 0.65 g/cm^3. The logs releases on the flow surface by opening the bottom of the basket. This instant release of the wood pieces was modeled after the woody debris inflowed by landslides on valley slopes during floods.

2.4. Test Procedure

The mixed flow of sediment and water transported downstream along flume bed after clear water supplied from a water tank at the upstream flume end. The mixed flow was almost clear due to less sediment transport.

The flow was in almost steady state in around 1.0 minute after the arrival of flow front at the model bridge. At the same time logs in the basket were released on the flow surface. The congested logs moved to the model bridge in the flume. The model bridge trapped some logs and formed an accumulation (Fig. 3). The other logs washed away through the model bridge

Flow rate per unit was measured by catching the outflow water in a container at the downstream end. Four video cameras were placed in the vicinity of the flume to investigate behavior of wood pieces at the model bridge. The first video camera was installed on the tops of the flume. The second and the third video cameras were put on the right-hand flume side and in front of the model bridge, respectively. The fourth video camera was set up near the downstream flume end. Table 1 presents the experimental condition. Twenty two runs were performed. The duration of each run was around 15 minutes.

2.5. Measurement of characteristic quantity of log jam

The number of wood pieces trapped and accumulated at the bridge was counted during and after the experimental runs. Plan and cross-sectional views of the log jam were taken by cameras. These photos were used for the evaluation of the apparent volume of log jam.

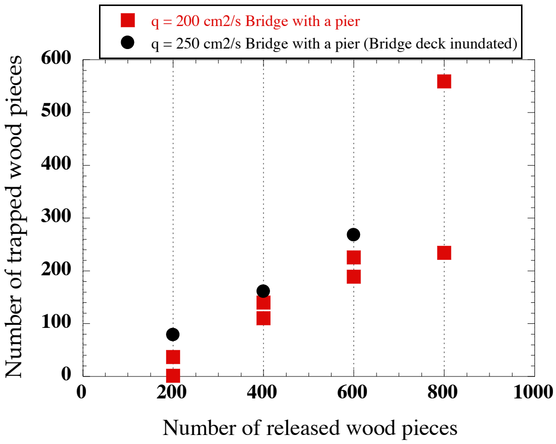
Table 1. Experimental condition.

No	Bridge with a pier Number of released wood pieces	Discharge	Bridge without pier Number of released wood pieces	Discharge
1	400	246	600	296
2	200	246	400	301
No	Bridge with a pier Number of released wood pieces	Discharge	Bridge without pier Number of released wood pieces	Discharge
3	600	246	800	298
4	600	200	600	294
5	400	200	600	300
6	200	200	400	300
7	600	201	800	298
8	400	201	400	299
9	200	201	200	299
10	800	197	800	301
11	800	197	600	300

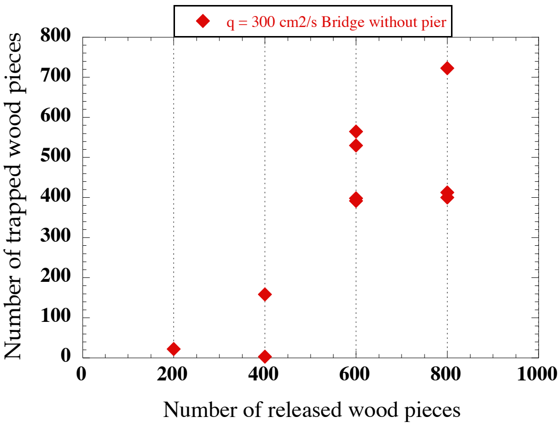
(a)

(b)

Fig. 3. (a) A front view of typical of log jam formed by model bridge without pier; (b) A front view of typical of log jam formed by model bridge with a pier.



(a)



(b)

Fig. 4. (a) A Relationshipp between number of trappped wood pieces and number or released wood pieces; (b) Ratio of traped wood pieces and released wood pieces.

3. Experimental results

3.1. Log jam at model bridges

Fig. 4 shows the relationship between the number of trapped wood pieces and that of the released wood pieces because of model bridge with a pier and model bridge without pier. The fraction of trapped wood pieces is plotted against the overall number of wood pieces in Fig. 5. The wood fraction trapped by the model bridge with a pier and the bridge without pier increase with the overall number of released wood pieces. Whereas, the wood friction trapped by model bridge with a pier increases significantly with the overall number of released wood pieces. However, the friction for model bridge without pier decrease from the overall number of released wood pieces larger than 600 pieces.

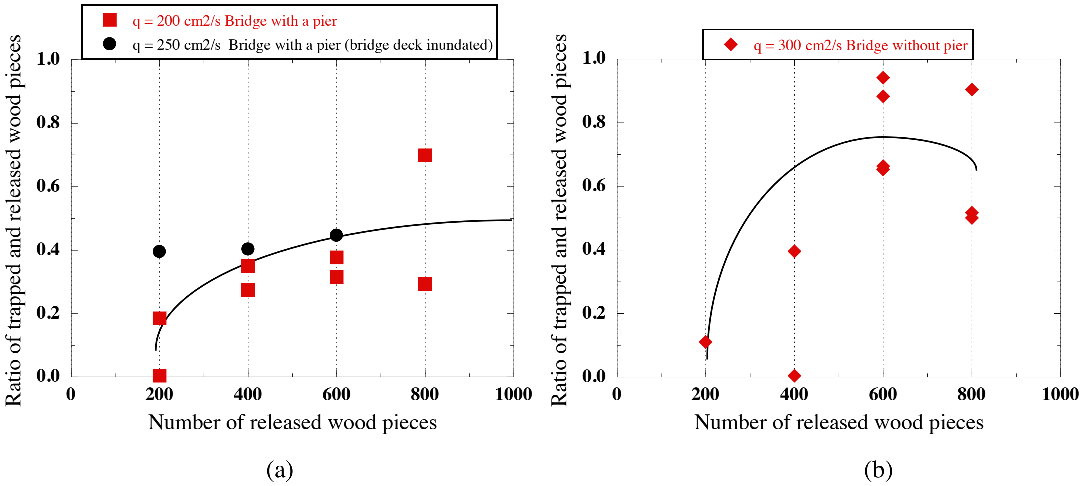


Fig. 5. (a) A Relationship between number of trappped wood pieces and number or released wood pieces; (b) Ratio of traped wood pieces and released wood pieces.

3.2. Relationship between log jam and model bridges

A bridge in rivers becomes an obstruction to floating woody debris during flood event. 'shaded area' (A_o) of bridge in river was proposed. Shaded area was defined as frontal area of the model bridge projected onto a plane perpendicular to flow direction (Fig. 6); it was determined as follows

$$A_o = L_x t_b \qquad \textit{for bridge without pier} \tag{1}$$

where L_x = length of an accumulation and t_b = bridge thickness

$$A_o = L_x t_b + L_y W_p \qquad \textit{for bridge with a pier} \tag{2}$$

where L_x = length of an accumulation; t_b = bridge thickness; L_y = length of pier that formed log jam and W_p = width of pier

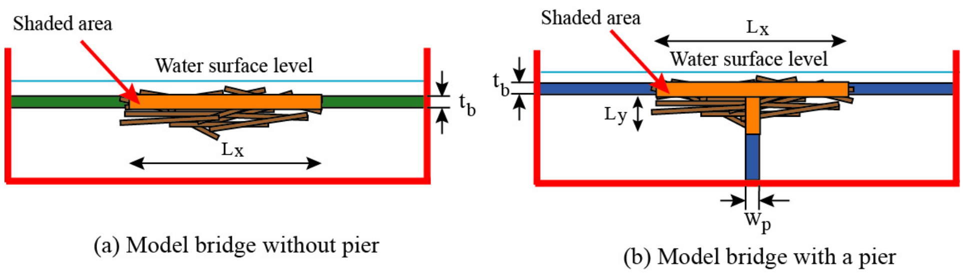


Fig. 6. (a) Shaded area of model bridge without pier ; (b) Shaded area of model bridge with a pier.

The apparent volume V_{wd} of log jam is plotted against 'shaded area' A_o of the model bridges in Fig. 7. An empirical equation is proposed as follow:

$$V_{wd} = CA_o^{\alpha} \tag{3}$$

where C = 2.5 and $\alpha = 3/2$.

The equation is found valid for the relationship of log jam and the model bridges in laboratory experiments. Therefore, the volume of woody debris jam can be predicted by evaluating the shaded area of an obstruction in rivers during flood event.

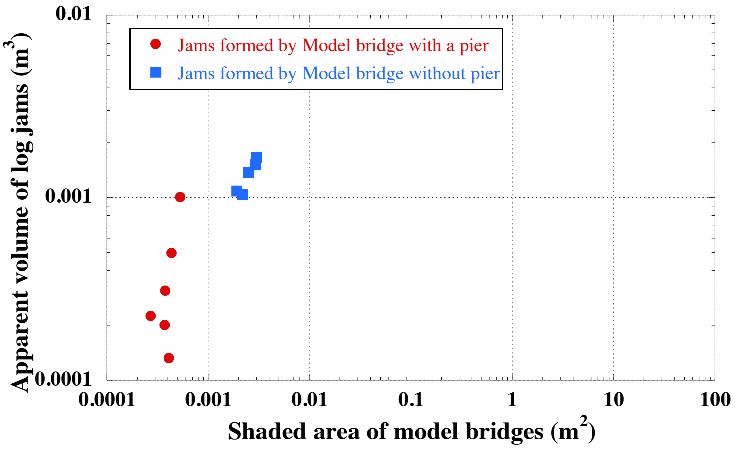


Fig. 7 (a) Relationship between shaded area of model bridge and apparent volume of log jam

4. Conclusion

The results of this study indicate log jam at model bridges is determined by 'shaded area' of the obstruction. Then, an empirical equation for predicting the volume of log jam at two different model bridges was proposed. This investigation into logs trapped by model bridges are still in progress and seem likely to confirm the empirical equation.

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